

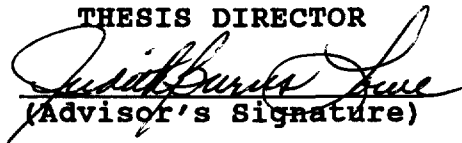
CALCIUM

AN HONOR'S THESIS (HONRS 499)

BY

WENDI L. RACETTE

THESIS DIRECTOR

  
(Advisor's Signature)

BALL STATE UNIVERSITY

MUNCIE, INDIANA

APRIL 26, 1991

EXPECTED GRADUATION DATE: MAY 1991

## Table of Contents

I	Introduction	3
II	Calcium's Function .....	3
III	Calcium Absorption and Retention .....	7
	A Vitamin D .....	10
	B Protein .....	11
	C Fiber .....	12
	D Phosphorus .....	13
	E Alcohol .....	14
IV	Supplements .....	15
V	Foods .....	18
VI	Osteoporosis .....	21
	A Risk Factors .....	23
	1 Sex .....	23
	2 Race .....	24
	3 Menopause .....	25
	4 Lifestyle .....	26
	B Secondary Factors .....	27
	C Clinical Features .....	27
	D Prevention and Treatment .....	28
VII	Amenorrhea .....	30
	A Causes .....	31
	B Treatment .....	32
VIII	Conclusion .....	33

## **INTRODUCTION**

Calcium is an essential mineral throughout life. It plays a significant role in the building and renewal of bone. Because several factors can hinder calcium absorption and retention in the body, it is important to obtain the recommended daily requirement of calcium. To obtain the daily requirement of calcium, foods high in calcium such as milk and milk products should be consumed. In addition, calcium supplements or special enzymatic products can be utilized for those individuals who experience milk allergies or require extremely high levels of calcium. With the growing elderly population, the incidence of osteoporosis has greatly increased. With this increase, calcium intake throughout life has received much emphasis. In order to combat osteoporosis, people should be aware of the factors that contribute to osteoporosis. Dietary calcium is vital in the prevention of osteoporosis. Education and awareness can help in the prevention of this painful disease. Calcium is important physiologically particularly in the blood and in the structure of the bone.

## **CALCIUM'S FUNCTION**

Although calcium accounts for only two percent of the adult human body, it is the most abundant mineral found in the body. Of this two percent, 99 percent of the body's

calcium is stored in the bone and teeth. In these structures, it provides strength and rigidity (1). Calcium in the bones and teeth consists of tiny crystals of calcium phosphate in the form of hydroxyapatite  $[3\text{Ca}(\text{PO}_4)_2 \text{Ca}(\text{OH})_2]$  and non-crystalline or amorphous calcium phosphate (1). The most readily available supply of calcium in the bones is in the trabeculae. The trabeculae consists of columns of crystalline calcium compounds. These crystalline compounds grow from the inner surface of the cavity at the end of the bone toward the center. Because of this orientation, they act as braces in strengthening the ends of the bones (2). Excess calcium and phosphorous can be stored in the trabeculae at the ends of the bones. When dietary calcium is abundant, the trabeculae is well developed. On the other hand, if dietary intake of calcium is inadequate, the calcium stored in the trabeculae is utilized (1). However, if over a long period of time dietary calcium has been inadequate and there has been no storage of calcium in the trabeculae, calcium will be withdrawn from the bone itself. This can eventually lead to bones that are easily broken or bent (1).

Calcium in the bones also prevents the alteration of the all-important blood calcium concentration (3). In addition, the trabeculae cavity contains blood vessels and intercellular fluids that come in close contact with the mineral material in the trabeculae cavity. Thus, the

mineral material can be readily absorbed to preserve the blood calcium concentration (2).

Unlike bone which undergoes calcium loss when the dietary intakes of calcium are insufficient, teeth do not readily release their calcium when body needs are not met by the diet (4). During the formative period for the development of tooth structure, sufficient intakes of calcium, phosphorous, protein, magnesium, fluoride, and vitamins A, C, and D are necessary for proper tooth formation. Diets that are deficient in these vitamins and minerals during the formation period may cause improper calcification of the tooth structure (4). Likewise, teeth after formation do not require additional calcium. Once they have erupted, teeth cannot repair themselves (1). The metabolic stability of the tooth structure, particularly dentin and enamel, are much greater than that of the bone structures (1).

The one percent of the body's calcium not found in the bones is in the blood and body fluids. For an average adult approximately ten grams of calcium exists in the extra cellular fluids and soft tissues (1). Three forms of calcium exist in the body fluids: ionized ( $\text{Ca}^{++}$ ), complexes of calcium formed with organic or inorganic acids, and protein-bound calcium. Ionized calcium is the physiologically active form (1). Though it consists of only one percent of the total body calcium, calcium in the blood and body fluids is vital for the proper functioning of the

body. It is necessary for a number of regulatory functions: muscle contraction and relaxation (which includes normal heartbeat), blood coagulation, transmission of nerve impulses, activation of enzymatic reactions, stimulation of hormone secretions, and integrity of intracellular cement substances (4). Moreover, a system of hormones and vitamin D tightly control the blood calcium concentration (3). For instance, in order to have proper blood clot formation, a normal level of ionized calcium must exist. Calcium is one of the fourteen essential factors involved in blood clot formation. It acts as a cofactor for the other thirteen proteins involved in the blood clotting process (3). Likewise, the transmission of nerve impulses and the normal level of excitability of the heart muscle and nerve tissues depends on the level of ionized calcium in the body (1). In addition, ionized calcium plays a role in the differential permeability of the cell membranes, which is necessary for the survival of the cells. Calcium also aids in the absorption of B<sub>12</sub> through the wall of the small intestine (1).

Three hormones play an important role in the regulatory functions of the body: calcitriol, the parathyroid hormone, and calcitonin. Calcitriol is an active metabolite of Vitamin D. Vitamin D aids in calcium absorption from the intestine (4). In addition, calcitriol participates in parathyroid hormone-induced mobilization of bone calcium (4). When blood calcium concentrations are low, calcitriol

limits the amount of calcium excretion from the body. The parathyroid hormone functions to decrease urinary excretion of calcium and activate the calcium from the bone when calcium levels are low (4). In contrast, calcitonin aids in decreasing high blood calcium concentrations when there is an abundance of calcium. Therefore, it inhibits the mobilization of calcium from the bones (4).

#### **CALCIUM ABSORPTION AND RETENTION**

At birth, calcium content of the body is approximately 28 grams. By maturity, calcium content of the body should be approximately 1200 grams to achieve proper skeletal growth. Therefore, calcium retention should be approximately 180 mg per day to attain normal skeletal growth (1,4). During infancy, early childhood, and adolescence, calcium needs increase due to rapid skeletal growth. Likewise, calcium requirements increase in pregnancy and lactation in order to accommodate the growing fetus. In particular, during these periods the efficiency of calcium absorption increases and calcium retention is at its peak (4).

In infancy, the calcium needs can be met by breast-feeding. Calcium in infant formulas is not as readily absorbable as calcium found in human milk. If a breast-fed infant receives 60-80 mg of calcium per kilogram of body weight, he will retain approximately 65 percent. However, if an infant who is fed cow's milk with carbohydrate added receives 170 mg of calcium per kilogram of body weight, the

infant will only retain approximately 30 percent of this amount (4). When adults do not consume adequate calcium, the efficiency of calcium absorption increases. Unlike adults, infants are unable to adjust to lower calcium intakes. For this reason, it is very important that infants consume the amount suggested by the RDA (4).

Calcium deposition throughout the growth period varies greatly. Maximum needs during early adolescence can be as much as 1200 mg per day (1). It is essential that calcium intakes meet the RDA during the growth period in order to have properly calcified bones. Though absorption is greater in childhood and adolescence, inadequate intakes of calcium may lead to growth retardation or abnormal or poorly calcified bone (1.4). Robert Heaney, M.D. et al of Creighton University found that after the age of fifteen, half of the women in the United States consume calcium levels below the RDA (4,5). This statistic is quite significant, since current research indicates that the calcium requirement for many adults is greater than the current RDA (4).

According to R.C. Gallagher, the efficiency of calcium absorption decreases with age (6). In addition, research has shown that serum levels of vitamin D-calciferol declines with age. It stimulates calcium absorption. Serum levels of vitamin D-calciferol probably decline as a result of its diminished synthesis (5). The serum level of the parathyroid hormone commonly rises with aging. This may



cause calcium to be resorbed from the bone. Likewise, the loss of calcium through the urine accelerates with age (5). These factors indicate the importance of adequate calcium intake to offset the age-related decrease in calcium absorption.

In women before menopause, calcium is resorbed at a rate of 25 mg per day whereas resorption in postmenopausal women increases to 50 mg per day (7). Therefore, special attention should be given to adequate calcium intakes for women who are approaching their menopausal years. In Robert Heaney's study which included 130 normal women between the ages of 30-35, he found that 1200 mg of calcium per day was necessary to attain zero calcium balance. At this level of calcium consumption, there would be no negative effects on the bone. Further findings by Velimar Matkovic et al showed that men consuming a daily intake of calcium from 800-1100 mg had a greater peak bone mass at age forty and fewer hip fractures at all ages than men consuming low calcium diets, consisting of 350-500 mg per day (4). A greater peak bone mass at 30-40 years of age seems to afford some protection against bone resorption and bone fractures occurring in later life (4).

In general, only twenty to forty percent of the calcium consumed is absorbed (1). Various factors affect the efficiency of calcium absorption.

## **Vitamin D**

Vitamin D aids the body in making the calcium and phosphorous available in the blood that bathes the bones to be deposited as the bones mineralize (3). Blood concentrations of calcium and phosphorous increase through vitamin D in three ways. Vitamin D stimulates calcium and phosphorous absorption from the gastrointestinal tract. Moreover, vitamin D helps in the removal of calcium from the bones for use in the blood. Also, it stimulates calcium retention by the kidneys (3). Metabolites and analogues of vitamin D may either promote intestinal calcium absorption, improve calcium balance, or both (1). In order for vitamin D to be biologically active, it must be converted to calcitriol. The hormonal form of vitamin D, calcitriol, is the governing force in the regulation of the intestinal absorption of calcium (4).

The results of inadequate dietary intake and inadequate tissue levels of vitamin D and its hormonal forms are impaired calcium absorption and bone status (9). Through sunlight exposure, vitamin D can be synthesized under the skin. Vitamin D synthesized from the sunlight along with a balanced diet usually is adequate vitamin D nutrition for most adults (8, 10). For older people vitamin D nutrition becomes very significant, because calcium is not absorbed well in the intestines of older people. Likewise, many older people stay indoors and are unable to attain sunlight.

Since it is necessary for optimal calcium absorption, vitamin D should receive special attention.

### **Protein**

A high dietary intake of protein, which is typical of many Americans and other Westerners, tends to increase the urinary excretion of calcium (1,5). However, animal protein may cause a smaller increase in urinary calcium loss than vegetable protein, because it has a higher phosphate content (5). Because of the acidic nature of their metabolic end products (sulfate and hydrogen), sulfur containing proteins enhance calcium excretion. When dietary protein intake is high, a negative calcium balance occurs. This results because of the increased urinary calcium without a concomitant increase in calcium absorption (11,12). Protein intakes in the U.S. and Canada double those that are recommended in both the U.S. and Canada (3). The rural Bantu women of South Africa, who exist on a vegetarian diet, secured only half of the calcium of the Caucasian controls in an experiment by Solomon. Yet, they had one-tenth as many hip fractures as their Caucasian counterparts (9). Solomon found that protein differences in the diet have an important effect on calcium status in the body (9). With an increase of dietary protein (with dietary protein as an isolated nutrient), urinary calcium increases proportionately (13).

## **Fiber**

Fiber consumed in large amounts has a certain chelating action on calcium, which can increase calcium loss in the stools (6,13). Larger stools produced by consuming excessive intakes of dietary fiber can cause large losses of trace minerals (13). According to Sandstead et al, calcium requirements increase by 150 mg per day when fiber is increased by 26 grams (13). Controversy exists surrounding the effects of fiber on calcium absorption. Some researchers postulate that mineral absorption depression is more the result of phytate content than of the total amount of fiber. Other investigators support that phytate has little effect on calcium absorption (14). According to some researchers, the calcium in certain vegetables is not absorbed as readily because of the presence of oxalate. Moreover, phytates bind calcium and make it less available for intestinal absorption. Likewise, oxalates, which are found in large amounts in spinach and other vegetables, bind calcium within the intestinal tract. Some common foods that contain phytic acid are oatmeal and other whole-grain cereals. Oxalic acid is found in beets, rhubarb, and spinach (3). It is possible that a combination of high phytate and high fiber diets hinders calcium absorption more than either factor by itself (9). However, fiber, in general, decreases calcium absorption. Therefore, individuals consuming large amounts of fiber should increase their consumption of calcium-rich foods (3).

## **Phosphorous**

Calcium absorption is not significantly affected by dietary phosphorous according to current evidence (11). Even though a diet high in phosphates does not affect overall calcium balance significantly, it tends to decrease urinary calcium excretion while increasing fecal calcium excretion (5). Moreover, Heaney et al concluded that calcium balance is not appreciably influenced by variations in phosphorus intake. Various levels of phosphorous intake have obvious effects on calcium handling and bone remodeling; however these effects cancel each other (11). According to a study done by Spencer et al, increasing phosphorous intake of adult males from 800-2000 mg per day and varying the levels of calcium intake from 200-2700 mg per day has no effect on calcium balance (11).

Concern about high phosphorous intakes centers on the replacement of milk with soft drinks, and the high consumption of phosphorous containing foods. Because phosphorous is readily available in commonly consumed processed foods, phosphorous intakes have exceeded the RDA of 800 mg per day by nearly 50 percent (4). Researchers suspect that these factors may have an adverse effect on calcium absorption (4). The fact that soft drinks containing phosphate replace milk in many diets gives cause for concern. Milk supplies a significant amount of calcium to the diet. Unless other calcium-rich foods are consumed,

there will be a deficiency of calcium in the diet. Therefore, phosphate drinks should not be used interchangeably with milk.

### **Alcohol**

According to L.H. Allen, patients with chronic alcoholism exhibit a high degree of bone demineralization (11). Several factors contribute to calcium malabsorption in chronic alcoholics. For instance, steatorrhea reduces the intestinal absorption of calcium. Likewise, alcohol decreases vitamin D absorption, which reduces calcium absorption. Also, the hydroxylation of vitamin D is impaired by the cirrhotic liver as a result of chronic alcohol consumption (11). Liver damage also affects calcium utilization and contributes to bone loss. A disturbance in fat absorbance due to reduced pancreatic function is another possible cause of impaired calcium absorption (6).

Calcium consumption may decrease as a result of alcohol. Alcohol may decrease appetite, resulting in the absence of calcium-rich foods in the diet. Likewise, many alcoholics in trying to maintain their weight eat nutritionally poor diets. Thus, calcium along with many other nutrients fails to appear in the diet. Special attention should be paid to growing adolescents whose calcium needs are great. Alcoholic adolescents are especially susceptible to calcium deficiency (4).

Several factors influence calcium retention and absorption. For instance, age and the amount of calcium consumed affect calcium absorption and retention. However, age and calcium intake are not the only factors that control calcium retention and absorption. For optimal calcium absorption and retention, vitamin D must be present either through the diet, through exposure to sunlight, or a combination of both. Likewise, intakes of fiber, phosphorous, protein, and alcohol influence the degree of calcium absorption and retention.

Because calcium absorption and retention is affected by several factors, meeting the RDA for calcium is very important. Often, people are unable to consume the RDA in their diets. In order to obtain the proper amount, people commonly use calcium supplements. There are numerous calcium supplements which vary in the percentage of calcium and effectiveness.

#### **SUPPLEMENTS**

The Recommended Daily Allowance for adults for calcium is 800 mg per day. According to the Osteoporosis Consensus Conference, the actual intake for adults is only 450 to 550 mg per day. Likewise, the conference states that women who have passed menopause may require as much as 1500 mg per day (15). Calcium supplements are often used to attain these allowances. Since 1982, sales and consumption of calcium supplements has increased. However, the best source of

calcium is through food sources (16). Nutrient imbalances are one reason calcium supplements should be used as a last resort. Robert Heaney reports that large calcium supplements have been shown to interfere with iron absorption (16). This happens as a result of a limited total intake, and most persons using calcium supplements have limited total intakes. Likewise, another problem with calcium supplements is that most supplements on the market today have not been adequately tested for bioavailability (16). Similarly, calcium supplements often have low calcium content which requires several doses throughout the day. However, for lactose intolerant persons or those individuals who cannot use dairy products regularly, calcium supplements can provide an alternative.

Calcium carbonate is 40 percent calcium and is usually the cheapest form of supplement available. It has been extensively tested. Unfortunately, in individuals who lack sufficient stomach acid calcium carbonate is not absorbed well. Likewise, calcium carbonate may cause abdominal distention from carbon dioxide release, and it may cause constipation. Examples of calcium carbonate are Tums Antacid, Caltrate 600, Bio Cal, and Cal-Sup (16). Supplements, such as Tums and other similar products, contain magnesium phosphate to eliminate constipation. However, this amount of magnesium can interfere with calcium absorption.



Moreover, calcium lactate, a soluble salt, is 13 percent elemental calcium (17). Because it contains relatively little calcium, the pill size or number must be increased in comparison to calcium carbonate. Likewise, calcium citrate-maleate has been thoroughly tested. It has a level of absorption that is slightly greater than food calcium (16). Supplements that are not recommended are dolomite and bone meal. In addition to 22 percent elemental calcium, dolomite contains magnesium chloride, iron, and phosphorous. Although dolomite is a major ingredient in several antacids. It may be contaminated with such toxic metals as arsenic, mercury, lead, cadmium, and others (4). Similarly, bone meal contains 31 percent elemental calcium and other minerals such as phosphorous, sodium, magnesium, potassium, sulfur, copper, and iodine. It may also contain toxic metals such as arsenic, mercury, lead, cadmium, and others (4). Because calcium supplements have varied effects on individuals, supplements should be selected that provide the greatest calcium absorption and that have insignificant adverse effects. Calcium supplements may interfere with the absorption of other nutrients. Therefore, the total nutritional picture should be considered when choosing a supplement.

## FOODS

Eating foods rich in calcium is the best way to meet the RDA for calcium. Milk and milk products, green leafy vegetables, and some protein sources (such as shellfish) contain calcium almost exclusively (3). Milk and milk products rank as the best nutritional sources of calcium, because they are high in calcium content and readily absorbable. Moreover, milk alone is highly utilized in the bodily processes, and even with pasteurization it remains readily available for absorption. The RDA of 800 milligrams of calcium for most adults can be met by drinking 2 3/4 cups of milk (whole, skim, or lowfat) per day (4). In addition to milk, lowfat yogurt is an excellent source of calcium. One cup of plain yogurt contains more calcium than an equivalent amount of milk (18). Likewise, cheese provides another calcium alternative. Because they have a lower water content, hard cheeses have a higher calcium content than softer cheeses. For instance, cottage cheese contains about 1/7 of the amount of calcium as a hard cheese such as cheddar. However, one cup of cottage cheese is equivalent to one half of a cup of milk in calcium content. Though it does not have as much calcium as other milk products, ice cream provides another alternative calcium source. Because of their high calcium content and the nutrients such as lactose and vitamin D (which enhance calcium absorption) that they contain, fortified milk and dairy products are important sources of calcium for the diet. (4).

The importance of drinking milk cannot be stressed enough. If milk allergies are not present, milk should be utilized in the diet. In a study by R.B. Sandler, milk consumption in childhood and adolescence appeared to have several roles. Milk is necessary for growth and development as well as assuring optimal peak of bone mass within genetic limits. According to Robert Recker's study, milk does not suppress bone remodeling as severely as calcium carbonate (19). Therefore, milk is advantageous, because it is effective, inexpensive, and easily available.

Although milk and milk products provide numerous health benefits, they also have some pitfalls. For instance, one cup of regular (10 percent fat) ice cream has 14 g of fat and 257 calories. Though it provides 194 mg of calcium, this amount of ice cream is high in fat and calories. With added flavorings and other ingredients, ice cream can be even higher in fat and calories. Likewise, cheese, especially hard cheese, is high in fat and calories. Whole milk is another milk product that is high in fat. One cup of 3.5 percent fat whole milk has 9 g of fat. The high fat content in these milk products may contribute to high cholesterol levels. Total elimination of these products is not necessary. These foods can be eaten in moderation. Moreover, low-fat or skim products can be substituted for high fat milk products with the advantage of fewer calories and lower fat content.

In addition to milk and milk products, fruits and vegetables can provide calcium to the diet. Green and leafy vegetables such as broccoli, kale, bokchoy, collards, turnip greens, mustard greens, and dandelion greens can be excellent sources of calcium (4). A large amount of these vegetables must be consumed to obtain the daily requirement for calcium. They contain less calcium in comparison to milk. Unlike milk, some coarse green leafy vegetables contain oxalates that hinder calcium absorption. Therefore, calcium in many vegetables is not as readily absorbed as a result of the presence of oxalic acids. Oxalate is present in asparagus, beet greens, chard, dandelion greens, parsley, sorrel, spinach, and rhubarb (20). Likewise, some vegetables provide less calcium than expected, because they contain fiber which may hinder calcium absorption (4).

In the meat group, calcium is most abundant in canned sardines and salmon which have been packaged with their soft edible bones (4,20). To obtain the most calcium from sardines and salmon, the bones must be consumed. Only a negligible amount of calcium is provided when the bones are not consumed, because almost the entire amount of calcium is found in the bones (4). Moreover, shellfish, almonds, Brazil nuts, dried beans, and tofu are also good sources of calcium (4,18). Tofu, which is soybean curd, must be processed with calcium sulfate to have optimal calcium content (4,20).

## OSTEOPOROSIS

Osteoporosis is a bone disease in which bone mass is reduced to a point where structural fracture may occur (5). Osteoporotic bones are brittle, fragile, and weak which makes them more susceptible to fracture (18). Unlike normal bone, osteoporotic bone cannot withstand everyday common stresses (4). William A. Peck, M.D. states that osteoporosis is a reflection of inadequate accumulation of bone tissue during growth and maturation, excessive losses thereafter, or a combination of both (8). Although early habits and lifestyle influence and possibly precipitate osteoporosis, the disease often goes unnoticed until it has reached its advanced stages, because it cannot be detected by conventional x-ray until loss of calcium in the bone is 25 to 40 percent. Fractures at this point are highly likely (4). Likewise, blood samples provide no indication of calcium deficiency, because blood calcium remains normal regardless of what the bone content may be (3). Since osteoporosis is often discovered in its latent stages, preventative measures need to be taken to reduce its likelihood. Most often the first warning that bones are thinning and becoming porous is a fracture in the hips or wrists. Bone porosity rarely shows up on x-rays even when 1/3 of the bone mass has been lost. Any bones can be affected by osteoporosis, but most often it will appear in the bones of the forearm or spine (20). In the elderly, the

majority of the fractures occur in the vertebrae, wrist, hip, shoulder, and knee joint (20).

According to the U.S. National Institutes of Health between two and five million Americans seek help each year for problems related to osteoporosis. Likewise, 15 to 20 million people have some degree of osteoporosis (5). Two classes of osteoporosis have been identified and each has overlapping features. The most common form of osteoporosis is primary osteoporosis, and it subdivides into postmenopausal (type I), aging associated (type II), and idiopathic (5). Postmenopausal osteoporosis correlates to estrogen deficiency and loss of trabecular bone in the vertebrae and in the wrist (8). Most often this occurs in postmenopausal women or in young women with amenorrhea (8). Moreover, aging associated, which was previously senile osteoporosis, affects a majority of elderly individuals who are over the age of 70 to 80 years old. Fractures of the humerus or hip commonly occur in type II or senile osteoporosis. Type II osteoporosis also occurs in men as well as women (5,8). In addition, type II shows a loss of cortical bone as well as trabecular bone (17). In contrast, idiopathic osteoporosis affects premenopausal women and middle-aged men or younger. There is no known cause for idiopathic osteoporosis. The other major class of osteoporosis is secondary osteoporosis. Loss of bone tissue in secondary osteoporosis results from an identifiable agent or disease process. Secondary osteoporosis affects men,

women, and children. It is caused by an identifiable catalyst such as an endocrine disorder or drugs (20). Moreover, secondary osteoporosis can result from immobilization or disuse of the bone. Prolonged bed rest, paralysis, confinement to a wheel chair, or periods of weightlessness (common with astronauts) localize osteoporosis (20). Closer scrutiny of primary and secondary osteoporosis is necessary to understand the destructiveness of the disease. Primary osteoporosis causes 1.3 million fractures annually in the U.S. of which there are 250,000 hip fractures (8). With the increasing life expectancy, osteoporosis represents a serious problem for the future as well as today. Currently, the annual cost of osteoporosis is estimated to be at seven to ten billion dollars (8).

## **Risk Factors**

### **Sex**

Osteoporosis afflicts eight times as many women as men (4). There exist several reasons for the higher incidence of osteoporosis among women. For example, men have 30 percent greater bone mass at maturity. Likewise, women tend to weigh less and have smaller muscles (20). Consistently throughout their lives, men consume more calcium than women. In between the ages of 15 and 50, men consume twice as much calcium in their diets as women (4). Similarly, men meet or go beyond the RDA on any given day up to age 64. In contrast, women from age twelve on consistently show low

mean daily calcium intakes. Moreover, osteoporosis more commonly afflicts women, because bone loss begins at an earlier age for women than in men. Menopause accelerates bone loss which puts postmenopausal women at the greatest risk for osteoporosis (4). Unlike men, women experience negative calcium balance in their later years. Due to pregnancy and breast feeding, which require higher calcium intakes, the calcium reserves in the bones of women may be depleted. This often results when the required higher intakes of calcium are not met. Also, women have longer life expectancies than men. Since bone loss increases with age, the greater longevity of women puts them at greater risk for osteoporosis than men (4). An additional factor that favors osteoporosis in women is the cessation of estrogen in postmenopause. Estrogen has a protective effect on bone. In contrast, men do not have a sudden decline in sex hormones (7,20).

#### **Race**

In addition to the sex of an individual, the particular race and habitus of an individual helps determine those individuals at the greatest risk for suffering osteoporosis. Those individuals at the greatest risk are those who were born in or have ancestors from: The British Isles, Northern Europe, China, Japan, Arctic Alaska, and Arctic Canada (7,20). Most often individuals from these ethnic origins have small skeletal frames. Lower bone density is associated with petite or thin women. Skin pigmentation is



another risk factor. Generally, the risk increases with the degree of fairness of the complexion. Statistics show that white women are most often afflicted by osteoporosis. Similarly, one-fourth of all the women in the U.S. by the age of 65 will have had one or more fractures (20). The incidence of osteoporosis in black people falls below that of white people, because black people tend to have ten percent greater skeletal bone mass at maturity and larger muscles (Larger muscles stress the bones more and protect against osteoporosis) (20). White women have the lightest skeletons while black men have the heaviest. Both, black women and white men have intermediate weight skeletons. Thus, white women suffer the greatest risk, because they have less bone to lose (8).

### **Menopause**

Lowered estrogen levels, that are associated with faster bone mineral loss, occur in women at menopause. This increases the susceptibility for osteoporosis (18). Likewise, women, who have had their ovaries removed before their natural menopause, have a 50 percent risk of accelerated onset of osteoporosis if they bypass hormone replacement therapy (20). Menopause, that is surgically induced, rapidly increases bone loss in both the appendicular and the axial skeleton (8). Amenorrheic women, like postmenopausal women, also have accelerated bone loss (18). Due to the cessation of their menstrual periods, amenorrheic women have low estrogen levels (18). In

addition, women with anorexia nervosa or bulimic women experience reduced bone mass similar to women at menopause. Females who have formerly had anorexia nervosa may still have reduced bone mass throughout their lives which puts them at high risk for osteoporosis in postmenopause.

### **Lifestyle**

Lifestyle determines to a certain degree the amount of risk for osteoporosis. For instance, increased incidence of fracture after a slight trauma occurs in smokers. Because smokers experience menopause on the average of 1.2 years earlier than their nonsmoking counterparts, they are at greater risk for osteoporosis (17). In general, the sooner an individual experiences menopause the greater the chances of suffering osteoporosis (20). Likewise, smokers have lower serum estrogen levels during estrogen replacement therapy. Moreover, smokers tend to have lower body weights (17). Women who are underweight have a higher incidence for osteoporosis than overweight women (20). Obese individuals undergo less bone loss, because obesity protects against bone loss (8). Excessive alcohol intake also increases an individual's chances for osteoporosis (18). In the same respect, diet plays an important role in bone health. Inadequate calcium intake as well as high intakes of foods that interfere with calcium absorption heightens the risk for osteoporosis. Similar to diet, inadequate exercise relates to a higher risk for osteoporosis. Moderate exercise provides joint stress to the bone which increases

bone density and protects against osteoporosis. Bone maintenance correlates to regular physical exercise. However, women who exercise to the degree that they experience amenorrhea lose the beneficial effects because of their lower estrogen levels (17). In a like manner, stress is significant, because it may reduce the intestinal absorption of calcium which helps to maintain the skeleton. Moreover, stress (physical, emotional, or both) stimulates the adrenal hormones that result in bone depletion and urinary calcium loss (20).

### **Secondary**

Osteoporosis occurring from a secondary cause can be identified in 20 percent of women and 40 percent of men with spontaneous vertebral fractures. The most prevalent causes of secondary osteoporosis include early oophorectomy (in women), hypogonadism (in men), subtotal gastrectomy, chronic obstructive pulmonary disease, immobilization, and pharmacologic doses of glucocorticoids or thyroid hormones. Other causes are severe malnutrition, anorexia nervosa, alcoholism, and rheumatoid arthritis (20).

### **Clinical Features**

The characteristic symptoms of osteoporosis are back pain, loss of height, spinal deformity, and multiple fractures (4,8). Initially, osteoporosis occurs in the bones of the spine and forearm. Later, osteoporosis appears

in the bones of the upper thigh and hip (4). Back pain which is the most common symptom results from the collapse of one or more vertebrae (4,8). Ordinary activity can cause a vertebral fracture. Pain can range from mild to severe, and it can last for days or weeks before diminishing. An individual may experience pain-free periods during the early stages of progressive osteoporosis. However, if multiple compressional fractures have occurred, a continuous dull aching pain may develop. Compressional fractures lead to loss of height which usually ranges from 4-8 inches in total. "Dowager's hump" is characteristic of this loss of height and of osteoporosis (4,20).

#### **Prevention and Treatment**

A preventative measure for postmenopausal women for osteoporosis is estrogen therapy. This treatment has been shown to stop bone loss in postmenopausal women up until the cessation of the treatment (17). Consideration must be given to the harmful effects of estrogen. For women who are already at risk for cancer of the endocrine responsive organs, estrogen therapy may not be the best treatment (5). Risk of endometrial cancer increases by three to eightfold during estrogen therapy (8). The risk factor rises in conjunction with the duration and the strength of the estrogen preparation (5).

Calcitonin, a naturally occurring hormone, may slow the breakdown of bone by osteoclasts (5). It has been approved

by the FDA. However, calcitonin is expensive and must be injected daily. Likewise, the form of calcitonin currently available has a slightly different structure from that which is secreted by humans. As a result, antibodies may form because of the difference in protein structure; and thereby decrease its effectiveness. Calcitonin's high degree of safety is its greatest advantage. It has minor side effects which rarely appear (8).

Several other agents for treatment of osteoporosis have been suggested. Fluoride treatment, which stimulates trabecular bone growth, has been investigated. However, fluoride displays such side effects as gastric irritation, tendonitis, and possibly cortical thinning. Other treatments include anabolic steroids, low-dose parathyroid hormone, and thiazide diuretics all of which are under investigation (5,8). Calcium intake has a great impact on skeletal growth and maintenance. Bone tissue and a reduced hip fracture frequency has been shown in populations that consume adequate calcium in their diets (8).

Moderate exercise aids in the prevention of osteoporosis by increasing bone density. Men who exercise beyond the point of moderation do not appear to experience any ill effects. However, many women who exercise beyond the point of moderation experience adverse effects. Often, women athletes who exercise excessively are afflicted with amenorrhea. Amenorrheic women cease to menstruate and develop low estrogen levels. Many women athletes feel that

the cessation of their menstrual periods is an advantage to them in competition. Unfortunately, amenorrhea may have long term ill effects.

#### **AMENORRHEA**

Amenorrhea, which is the abnormal absence or suppression of menstrual cycles, affects up to 50 percent of competitive runners, 44 percent of ballet dancers, 25 percent of noncompetitive runners, and only 12 percent of swimmers and cyclists (21). Also, amenorrhea commonly afflicts women with anorexia nervosa. Low circulating estrogens among amenorrheic individuals may result in increased urinary calcium excretion. This factor may cause negative calcium balance (21,22). Likewise, recent research shows that amenorrheic women have low bone mineral density in the lumbar spine. This suggests accelerated bone loss and impaired growth of bone mass. Amenorrhea may predipose young women athletes to suffer clinical osteoporosis in later life (21). In a study of vertebral mineral density in amenorrheic and eumenorrheic athletes, Drinkwater et al determined that while the amenorrheic group had an average age of 25 years, their bone density resembled that of women 51 years of age (22). Furthermore, Nelson et al found that bone mineral density of the lumbar spine was significantly lower in amenorrheic compared to normally menstruating runners. Circulating estradiol was also significantly lower (21).

## **Causes**

The cause of athletic amenorrhea remains unclear. It may occur because of changes in body composition, excessive exercise, low caloric intake, or physiological abnormalities (22). Abnormal calcium metabolism and increased bone resorption are also linked to athletic amenorrhea. A reduction in the trabecular bone mass due to bone resorption may increase the risk of developing exercise-related fractures over a short term. Over an extended period of time, athletic amenorrhea could block the achievement of maximum bone density. Without achievement of maximum bone density, the risk of developing postmenopausal osteoporosis increases (22). A study by Bullen et al showed that vigorous exercise, particularly if compounded by weight loss, can reversibly disturb reproductive function in women (23). Therefore, exercise and diet play an important role in athletic amenorrhea. Nelson's study also pointed to diet and exercise as causes of amenorrhea. He found that weight-bearing exercise and a low energy intake are factors in the development of amenorrhea. Likewise, he concluded that "the accretion of large bone mass in young trained women is not favored" (21). Gordon Wardlaw of Ohio State University states that "women need to find a balance of body weight and a level of exertion that allows for menstruation" (17).

## **Treatment**

Even though many women athletes are glad that they do not menstruate, this disorder should not be taken lightly. According to Jerilynn Prior, M.D. at the University of British Columbia in Vancouver, women athletes need to offset the effects of low estrogen levels on bone by increasing their calcium intake (24). Otherwise, the risk of developing postmenopausal osteoporosis will be increased. In a recent study of amenorrheic athletes, a decrease in the mileage per week brought about the resumption of menses and an increase in vertebral bone density (17). Less strenuous exercise might allow menses to resume and estrogen levels to return to normal. If this is not possible or menses do not resume, estrogen replacement therapy should be considered. This type of therapy is effective in amenorrheic athletes only if it is initiated during the first one or two years of menstrual dysfunction (24). Moreover, Jerilynn Prior states that athletic amenorrhea is reversible. Her recommendation for amenorrheic athletes if they want to get pregnant is to reduce their exercise through a decrease in intensity or mileage. Similarly, weight gain is advised if the individual is less than 18 percent body fat (24). Though it is reversible, athletic amenorrhea should be taken seriously because of its long and short term effects on bone and its hormonal abnormalities.



## CONCLUSION

Throughout life, calcium is very important for proper skeletal growth and maintenance. To obtain maximum skeletal growth, calcium intake should meet the RDA in childhood as well as in adulthood. By meeting the RDA for calcium, the risk of developing osteoporosis is reduced. Several factors influence calcium absorption. For instance, a diet high in calcium may be offset by high protein and fiber intakes. Likewise, calcium status can be reduced by other factors such as excessive alcohol, excessive exercise, and smoking. All of which contribute to lower bone mass and a greater risk of developing osteoporosis in later life. Since osteoporosis affects primarily older individuals, people need to learn what factors put them at greatest risk. With longer life expectancies, the incidence of osteoporosis will rise if proper precautions are not taken. In turn, with the rise in women competing in athletics, better understanding and greater awareness concerning amenorrhea needs to occur. Amenorrheic women should seek medical assistance to prevent bone loss which could put them at a greater risk for osteoporosis. With today's focus on osteoporosis, calcium's importance should not be overlooked.

## References

1. Anderson, L., M. Dibble, P. Turkki, H. Mitchell, and H. Rybergen. **Nutrition in Health and Disease.** 17th ed. Philadelphia: J.B. Lippincott Co., 1982.
2. Briggs, G. and D. Calloway. **Nutrition and Physical Fitness.** 11th ed. New York: CBS College Publishing, 1984.
3. Whitney, E. and E. Hamilton. **Understanding Nutrition.** 4th ed. St. Paul, MN: West Publishing Co., 1987.
4. National Dairy Council. **Calcium: A Summary of Current Research For the Health Professional.** Rosemont, IL: 1984.
5. U.S. Dept. of Health and Human Services. Proceedings of the National Conference on Women's Health 17-18 June 1986. Bethesda, MD. **Journal of the U.S. Public Health Service** (Supplement) July-August, 1987.
6. Paterson, C.R., and W.J. MacLennan. **Bone Disease in the Elderly.** Chichester: John Wiley and Sons, 1984.
7. Larson, K.A., and S.C. Shannon. Decreasing the Incidence of Osteoporosis-Related Injuries Through Diet and Exercise. **Public Health Reports** 99 (Nov-Dec. 1984): 609-613.
8. Peck, W., B. Riggs, and N. Bell. **Physician's Resource Manual on Osteoporosis.** National Osteoporosis Foundation CoMedica, 1987.
9. Kies, C. (Ed). **Nutritional Bioavailability of Calcium.** Washington, D.C.: American Chemical Society, 1985.
10. Willis, J. Please Pass That Woman Some More Calcium and Iron. **FDA Consumer** Sept. 1984.
11. Allen, L.H., Calcium Bioavailability and Absorption: A Review. **American Journal of Clinical Nutrition** 35 (1982): 783-808.

12. Holl, M., and L.H. Allen. Comparative Effects of Meals High In Protein, or Sucrose, or Starch On Human Mineral Metabolism and Insulin Secretion. **American Journal of Clinical Nutrition** 48 Nov. 1988.
13. Heaney, R.P., J.C. Gallagher, C.C. Johnston, et al. Calcium Nutrition and Bone Health in the Elderly. **American Journal of Clinical Nutrition** 36 (suppl) 1982: 986-1013.
14. Hunt, S., and J. Groff. **Advanced Nutrition and Human Metabolism**. St. Paul: West Publishing Co., 1990.
15. Miller, R. (Ed). Osteoporosis, Calcium, and Estrogens. **FDA Consumer** Nov. 1984.
16. Heaney, R.P. The Role of Calcium in Prevention and Treatment of Osteoporosis. **Physician and Sportsmedicine** 15 (Nov. 1987): 83-88.
17. Wardlaw, G. The Effects of Diet and Lifestyle on Bone Mass in Women. **Journal of the American Dietetic Association** Jan. 1988: 17-22.
18. Slavin, J. Calcium and Healthy Bones. **Physician and Sportsmedicine** 13 (Sept. 1985): 179-81.
19. Recker, R.R. and R.P. Heaney. The Effect of Milk Supplementation on Calcium Metabolism, Bone Metabolism, and Calcium Balance. **American Journal of Clinical Nutrition** 41 (1985): 254-263.
20. Mayes, K. **Osteoporosis: Brittle Bones and the Calcium Crisis**. Santa Barbara: Pennant Books, 1986.
21. Nelson, M.E. et al. Diet Status and Bone Status in Amenorrheic Runners. **American Journal of Clinical Nutrition** 43 (1986): 910-916.
22. Olson, R.E. (Ed). Bone Loss in Amenorrheic Athletes. **Nutrition Reviews** 44 (Nov. 1986): 361-363.
23. Bullen, B. et al. Induction of Menstrual Disorders By Strenuous Exercise. **New England Journal of Medicine** 312 (23 May 1985): 1349-1353.
24. Caldwell, F. Light-boned and Lean Athletes: Does the Penalty Outweigh the Reward. **Physician and Sportsmedicine** 12 (Sept. 1984): 139-145.